LOUDSPEAKER

[0001] This application claims the benefit of U.S. provisional No. 60/224,505, filed August 14, 2000.

FIELD OF THE INVENTION

[0002] The invention relates to a loudspeaker and, in particular, to a loudspeaker that uses a plurality of different exciters.

BACKGROUND ART

[0003] Bending wave panel loudspeakers are known, for example from WO97/09842 and counterpart U.S. application No. 08/707,012, filed September 3, 1996, both to New Transducers Ltd. In general, such speakers include a resonant bending wave plate and a transducer mounted on the plate to convert electrical signals into mechanical vibrations. The transducer excites the resonant bending wave modes in the plate, which then emit sound to create an acoustic output.

[0004] The properties of the acoustic radiator may be chosen to distribute the resonant bending wave modes substantially evenly in frequency. In other words, the properties or parameters, e.g. size, thickness, shape, material etc., of the acoustic radiator may be chosen to smooth peaks in the frequency response caused by "bunching" or clustering of the modes. The resultant distribution of resonant bending wave modes may thus be

such that there are substantially minimal clusterings and disparities of spacing.

[0005] In particular, the properties of the acoustic radiator may be chosen to distribute the lower frequency resonant bending wave modes substantially evenly in frequency. The number of resonant bending wave modes is fewer at lower frequencies than at higher frequencies and thus the distribution of the lower frequency resonant bending wave modes is particularly important. The lower frequency resonant bending wave modes are preferably the ten to twenty lowest frequency resonant bending wave modes of the acoustic radiator. The resonant bending wave modes associated with each conceptual axis of the acoustic radiator may be arranged to be interleaved in frequency. Each conceptual axis has an associated lowest fundamental frequency (conceptual frequency) and higher modes at spaced frequencies. By interleaving the modes associated with each axis, the substantially even distribution may be achieved. There may be two conceptual axes and the axes may be symmetry axes. For example, for a rectangular acoustic radiator, the axes may be short and long axes parallel to the short and long sides of the acoustic radiator, respectively. For an elliptical acoustic radiator, the axes may correspond to the major and minor axes of the ellipse. The axes may be orthogonal.

[0006] The transducer location may be chosen to couple substantially evenly to the resonant bending wave modes. In particular, the transducer location may be chosen to couple substantially evenly to lower frequency resonant bending wave modes. In other words, the transducer may be mounted at a location spaced away from nodes (or dead spots) of as many lower frequency resonant modes as possible. Thus the transducer may be at a location where the number of vibrationally active resonance anti-nodes is relatively high and, conversely, the number of resonance nodes is relatively low. Any such location may be used, but the most convenient locations for rectangular panels are the near-central locations between 38% to 62% along each of the length and width axes of the panel, but off-central. Specific locations found suitable are at 3/7, 4/9 or 5/13 of the distance along the axes; a different ratio for the length axis and the width axis is preferred.

[0007] A bending panel loudspeaker in the form of a ceiling tile is known from WO97/09843 and US 6,215,881, both to New Transducers Ltd. It is also known from WO97/09846 and US 6,031,926, likewise to New Transducers Ltd., to provide a bending panel loudspeaker with multiple exciters connected in parallel to an amplifier. Loudspeaker systems capable of broadcasting alarm signals, white noise to enhance privacy in an open plan office, and

music or speech are known; however, each signal source requires its own loudspeaker adapted to the particular signal to be broadcast. The present invention addresses the increased cost and space implications of such known systems.

SUMMARY OF THE INVENTION

[0008] Accordingly, the present invention is directed to a loudspeaker comprising a panel capable of supporting bending waves and at least two exciters mounted to the panel for exciting bending waves in the panel to produce an acoustic output, each of the exciters being adapted for connection to respective independent sources of drive signals.

[0009] The use of a single panel to support the exciters for two different signal sources significantly reduces the space requirements of the system as a whole as well as reducing the overall cost of the system. This is made possible by the bending mode operation of the panel which allows faithful reproduction of multiple excitation signals when applied simultaneously to the panel.

[0010] The invention also comprises a ceiling tile and a loudspeaker system incorporating such a loudspeaker.

[0011] The invention further concerns a method of operating a loudspeaker having a panel capable of supporting bending waves and at least two exciters mounted to the panel for exciting bending waves in the

panel to produce an acoustic output, comprising driving each of the exciters by an independent source of drive signals. The loudspeaker may have three exciters, one of the exciters being selectively driven such that the panel produces an alarm signal, another of the exciters being selectively driven such that the panel produces a signal conditioning signal, and the last of the exciters being selectively driven such that the panel produces an audio signal in the form of music and/or speech.

BRIEF DESCRIPTION OF THE DRAWING

[0012] For a better understanding of the invention a specific embodiment will now be described with reference to the accompanying drawing figure, which is a perspective view of a ceiling tile loudspeaker according to the invention.

DETAILED DESCRIPTION

[0013] A panel 1 shaped as a conventional ceiling tile has opposed top 3 and bottom 5 faces. The bottom face is intended to face into a room when the ceiling tile is fitted. The panel is capable of supporting resonant bending waves and the panel parameters are selected for a useful distribution of bending wave resonances in frequency, for example as taught in the aforementioned WO97/09842 and U.S. counterpart application No. 08/707,012, filed September 3, 1996 (the latter being incorporated herein by reference).

[0014] Such a panel is available, for example, from HONIPAN and comprises a core of aluminium honeycomb skinned on either side by Kraft paper and having a total thickness of 7mm. The anisotropic properties of the Kraft paper result in a panel in which the modal distributions are different for the two conceptual axes in spite of the panel itself having a square plan geometry (59.5cm x 59.5cm in the present example).

[0015] Three exciters 7,9,11 are mounted on the top face 3 of the panel. Exciter 7 is an alarm exciter for producing an alarm signal in a predetermined frequency band. Such a signal preferably has a sound pressure level of more than 90dB - in particular 100dB ± 5dB SPL (Sound Pressure Level) - at 1W, 1m. In a narrow frequency band around the predetermined alarm frequency, the level may exceed 100dB SPL.

[0016] To achieve this degree of power delivery into the panel, an exciter may be used having a voice coil with a high maximum current, or an exciter that delivers a high force to the panel for a given current or voltage input. Such an exciter is of the moving coil type manufactured, for example, by ELAC Elektroakustik, Germany and having a 37mm diameter voice coil and an operating bandwidth of 150Hz - 10kHz.

[0017] Exciter 7 is coupled to the panel at a location that couples well to the resonant bending wave mode or

modes at the predetermined frequency, as discussed above with regard to WO97/09842 and US 08/707,012. In the panel of the example, a preferential location on the panel top surface 3 is at 36.6cm and 25.4cm respectively relative to adjacent orthogonal edges of the panel.

[0018] A cable 8 electrically connects exciter 7 to alarm circuit 21 capable of providing the typical 20V operating voltage required by alarm exciters of the kind described above.

[0019] A signal conditioning exciter 9 is mounted on the panel for producing a signal conditioning signal, e.g. white noise to enhance privacy in an open plan office. The maximum frequency bandwidth required for signal conditioning is much greater than that required for an alarm signal. Consequently, the location of the signal conditioning exciter 9 is chosen so as to couple with a broader frequency band of resonant bending wave modes. As explained above, such a location has a relatively high number of vibrationally active resonance anti-nodes together with a relatively low number of resonance nodes. In the panel of the example, this location is at 36.6cm and 33.1cm respectively relative to adjacent orthogonal edges of the panel.

[0020] The exciter 9 itself also requires a broad frequency range, albeit at a different maximum sound pressure level to that of the alarm exciter (preferably

70dB to 90dB SPL, more preferably 90dB ± 5dB SPL). In the present example, these requirements are met by a moving coil exciter having a 25mm diameter voice coil of the kind manufactured by Zhejiang Tianle Group Corp., China. Such a device has an operating bandwidth of 80Hz to 18kHz and an input voltage of 10V which is supplied via cable 10 from a signal conditioning driver 20 which operates independently from alarm circuit 21.

[0021] Reference figure 11 indicates a third, background music exciter 11 mounted to the panel top surface 3. Since this exciter is intended for reproducing an audio signal, the quality of the signal output from this exciter generally needs to be highest. Consequently, the exciter may be coupled at the best available location or site for coupling to a broad frequency band of resonant bending wave modes, with the white noise exciter 9 being coupled at a worse location and the location of the alarm exciter 7 giving coupling over a yet narrower frequency band. In the present example, the best available location is at 26.4cm and 25.4cm respectively relative to adjacent orthogonal edges of the panel.

[0022] At 80dB to 100dB SPL, preferably 90dB ± 5dB SPL, the power requirement of the background music exciter 11 lies between that of the two other exciters. It is met in the example by a simple piezoelectric exciter having a typical operating bandwidth of 300Hz to 20kHz and

connected via a cable 12 to a driving source 22 of background music, speech, etc. which operates independently of the aforementioned alarm and signal conditioning circuits 21,20.

[0023] It will be appreciated that the present invention is not limited by what has been particularly shown or described - rather the scope of the present invention is defined only by the claims that follow.

[0024] For example, one or more of the exciters may be mounted in a recess in the panel rather than on the top face. Similarly, one or more of the exciters may be not be mounted directly on the panel but coupled to it by a coupling member.

[0025] Nor is the invention restricted to three exciters: for example, the signal conditioning exciter and the music exciter may be combined since the required bandwidth and efficiency are similar. Alternatively, a further exciter optimised to produce clear speech may be included in the panel.